Having ascertained the chromatic relations between sixteen colours selected from the spectrum, the next step is to ascertain the positions of these colours with reference to Fraunhofer's lines. This is done by admitting light into the shorter arm of the instrument through the slit which forms the eyehole in the former experiments. A pure spectrum is then seen at the other end, and the position of the fixed lines read off on the graduated scale. In order to determine the wave-lengths of each kind of light, the incident light was first reflected from a stratum of air too thick to exhibit the colours of Newton's rings. The spectrum then exhibited a series of dark bands, at intervals increasing from the red to the violet. The wave-lengths corresponding to these form a series of submultiples of the retardation; and by counting the bands between two of the fixed lines, whose wave-lengths have been determined by Fraunhofer, the wave-lengths corresponding to all the bands may be calculated; and as there are a great number of bands, the wave-lengths become known at a great many different points.

In this way the wave-lengths of the colours compared may be ascertained, and the results obtained by one observer rendered comparable with those obtained by another, with different apparatus. A portable apparatus, similar to one exhibited to the British Association in 1856, is now being constructed in order to obtain observations made by eyes of different qualities, especially those whose vision is dichromic.

II. "On the Insulating Properties of Gutta Percha." By Fleeming Jenkin, Esq. Communicated by Professor William Thomson. Received February 9, 1860.

(Abstract.)

The experiments described in this paper were undertaken with the view of determining the resistance opposed by the gutta-percha coating of submarine cables at various temperatures to the passage of an electric current.

The experiments were made at the works of R. S. Newall and Co., Birkenhead. The relative resistance of the gutta percha at various temperatures was determined by measuring the loss on short lengths

immersed in water. These experiments are described in the first part of the paper. The absolute resistance of gutta percha has been calculated from the loss on long submarine cables. These experiments and calculations are described in the second part of the paper.

Part I.

The loss of electricity was measured upon three different coils, each one knot in length. One was covered with pure gutta percha; the two remaining coils were covered with gutta percha and Chatterton's compound. The coils were kept at various temperatures by being covered with water in a felted tub; and the water was maintained at a constant temperature for twelve or fourteen hours before each experiment.

The loss or current flowing from the metal conductor to earth through the gutta-percha coating was measured on a very delicate sine-galvanometer. The loss from the connexions when the cable was disconnected, was measured in a similar manner. The electromotive force of the battery employed was on each occasion measured in the manner described by Pouillet. Corrections due to varying electromotive force and loss on connexions were made on the result of each experiment.

A remarkable and regular decrease in the loss was observed for some minutes after the first application of the battery to the cable; a phenomenon, which the author thinks may be due to the polarization of the molecules of gutta percha, or of the moisture contained in the pores of the gutta percha. The loss was therefore measured from minute to minute for five minutes, with each pole of the battery.

Nineteen tables containing the results, with the reductions and curves representing the results, accompany the paper. The following results were obtained from the first coil; this was prepared with Chatterton's patent compound. With a negative current between the limits of 50° and 80° Fahrenheit, the decrease of resistance is sensibly constant for equal increments of temperature; and the increase of resistance due to continued electrification is also nearly constant. At 60° the resistance increases about 20 per cent. in five minutes from this cause. With a positive current, similar results

appear between the temperatures of 50° and 60°; but the resistance is somewhat greater than with the negative current. The extra resistance due to continued electrification is unchanged by a change in the sign of the current. Above the temperature of 63° great irregularities occur in the observations, which could not even be included in regular curves. The difference in the resistance of the gutta-percha coating when the copper is positively and negatively electrified, may be caused by the contact between the resinous compound and the copper: no such difference was observed when pure gutta percha was in contact with the copper.

The curves resulting from the experiments on the second coil, which was covered with pure gutta percha, present an entirely different character from those resulting from the first coil. The copper and gutta percha were of the same size in these two coils. The resistance of pure gutta percha at low temperatures is greater than that of the compound covering. At 65° the resistance of the two coverings is equal; at higher temperatures the resistance of pure gutta percha diminishes extremely rapidly. The curves obtained with positive and negative currents are identical up to about 75°; a slight difference occurs above this temperature, which may have been accidental. The extra resistance is less with pure gutta percha than with the compound; it increases slightly at high temperatures, and is not affected by a change in the sign of the current.

The curves derived from the experiments on the third coil, which contained a smaller proportion of Chatterton's compound than the first coil, appear in some respects intermediate between those derived from the first and second coils. The extra resistance due to continued electrification was still greater in this coil than in the others. 40 per cent. of the entire resistance is at 70° due to this cause. This increase is believed to be due to the greater mass of gutta percha used in covering this coil, which was of larger dimensions than the two others.

Part II.

Professor Thomson has supplied an equation expressing the law which connects the resistance of a cylindrical covering, such as that of a cable, with the resistance of the unit of the material forming the covering.

Let S be the specific resistance of the material, or the resistance of a bar one foot long, and one square foot in section; let G be the resistance of the cylindrical cover of a length of cable L; let $\frac{a}{b}$ be the ratio of the external to the internal diameter of the covering; then

$$S=\frac{2\pi LG}{\log\frac{a}{b}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The resistance G was calculated from cables of various lengths, lying in iron wells at the works of R. S. Newall and Co., Birkenhead. The cables were not wet; but direct experiment proved that covering a sound iron-covered cable with water has no effect on the loss. The details of this experiment are given in the paper.

The resistance G was obtained in the following manner. The copper conductor of the cable to be tested was arranged so as to form a complete metallic arc with a battery of 72 cells and a tangent galvanometer: the deflection on this galvanometer was read and entered as the continuity test. Deflections were then read on the same galvanometer with the battery and several known resistances in circuit, for the purpose of measuring the resistance and electromotive force of the battery, in the manner described by Pouillet. The deflection caused by the loss was next read on a second tangent galvanometer: the same battery was used. This deflection was entered as the insulation test. The temperature of the tank containing the cable was observed by means of a thermometer inserted in a metal tube, extending from the circumference into the mass of the coil.

The relative delicacy of the galvanometers was ascertained by experiment, or, in other words, the coefficient was found by which the tangents of the deflections of the first were multiplied to render them directly comparable with the tangents of the deflections of the second galvanometer.

The resistances of the galvanometer coils, of the artificial resistance coils, and of the copper conductor of the cable were measured by Wheatstone's differential arrangement. Special experiments were made by means of this differential arrangement to determine the change of resistance of the copper conductor in the cable, produced by a change of temperature.

The equation (No. 2) $R=r(1+0{\cdot}00192t)$ gives the value of the resistance R of the copper wire at any temperature $t+a$ in function of the resistance r at any temperature a (Fahrenheit). The length and temperature of any coil being known, the resistance of the copper wire was thus at once obtained from the resistance of one knot at 60°, which was very carefully determined.

Now let G=resistance of cylindrical coating.

D=deflection called the continuity test.

d=deflection called the insulation test.

C=coefficient expressing the relative delicacy of the two galvanometers.

BR=resistance of the battery.

T_1=resistance of the coil of first galvanometer.

T_2=resistance of the coil of second galvanometer.

$$\text{Then } G=\frac{C \tan D\times(BR+T_1+M)}{\tan d}-BR+T_2+\frac{M}{2}\cdot \quad \ldots \quad (3)$$

G having been thus obtained in any desired units, S, the specific resistance of the material, can be at once obtained by equation No. 1, which appears from several experiments to give constant values for S when calculated from cables of different dimensions. In extreme cases, however, the influence of extra resistance would render the formula defective, especially after continued application of the current: thus the resistance of a foot-cube would be very different to that of an inch-cube.

The values of G for the covering of the Red Sea cable, after continued electrification for periods of one, two, three, four, and five minutes, were calculated in Thomson's Absolute British Units, from four sets of tests made specially for this purpose on four different cables, each about 500 knots long. Tables containing the results of these calculations accompany the paper.

A Table is also given of the resistance of the Red Sea covering after one minute's electrification, and after five minutes' electrification, at each degree of temperature, from 50° to 75° Fahrenheit. This Table was formed by means of the temperature curves described in the first part of the paper: this Table is here annexed (No. 1).

Similar Tables were given for the covering of the two experimental coils mentioned in the first part of the paper. The coil composed

of pure gutta percha, gave very regular and complete results. An abbreviation of the Table is annexed.

It was remarked that in the tests of the cable in the iron tanks, the resistance after five minutes' electrification was invariably greater with zinc than with copper to cable, whilst the reverse was the case with the single knot covered by water. The length of the cable, and the condition of immersion or non-immersion, have probably some influence on the phenomenon of extra-resistance. This phenomenon appears to the author to be of much importance, and to demand further investigation.

The values of G were also calculated from the daily tests of the cables during manufacture at many temperatures. These values agreed with those given in the Tables above described. The general results of the experiments may be summed up as follows.

The relative loss at various temperatures through pure gutta percha has been pretty accurately determined for all ordinary temperatures. To a less extent the same knowledge has been gained concerning two other coatings containing Chatterton's compound. The latter appears superior at high, and inferior at low temperatures.

Attention has been drawn to the considerably increased resistance which follows the continued electrification of gutta percha and its compounds. Some of the laws of this extra resistance have been determined, and some suggestions made as to the cause of the phenomenon.

The bounds have been pointed out within which formulæ may be used, which consider gutta percha as a conductor of the same nature as metals.

The resistance of gutta percha has been obtained in units, such as are employed to measure the resistance of metals; and by the use of Professor Thomson's formula, the specific resistance of a unit of the material has been fixed with some accuracy.

The resistance of other non-conductors, such as glass and the resins, may probably, by comparison with gutta percha, be obtained in the same units.

Incidentally, the increase of resistance in copper with increased temperature has been given from new experiments; and it has been shown that the insulation of a sound wire-covered cable is little, if at all, affected by submersion.

Finally, tables and formulæ are given by which the resistance of, or the loss through any new cable coated with gutta percha, may be at least approximately estimated:—

TABLE I.

Specific Resistance in Thomson's Units of the Red Sea Covering at various Temperatures.

Tempera-ture.	Zinc to cable.		Copper to cable.	
	After electrification for one minute.	After electrification for five minutes.	After electrification for one minute.	After electrification for five minutes.
60°	2162×10^{17}	3330×10^{17}	2239×10^{17}	3405×10^{17}
65	1810× „	2947× „	1720× „	2770× „
70	1460× „	2378× „	1318× „	2239× „
75	1160× „	1753× „	1000× „	1739× „

TABLE II.

Specific Resistance in Thomson's Units of pure Gutta Percha at various Temperatures.

Tempera-ture.	Zinc to cable.		Copper to cable.	
	After electrification for one minute.	After electrification for five minutes.	After electrification for one minute.	After electrification for five minutes.
50	4113×10^{17}	5663×10^{17}	4113×10^{17}	5663×10^{17}
55	2917× „	3636× „	2917× „	3636× „
60	2163× „	2549× „	2163× „	2549× „
65	1634× „	1858× „	1634× „	1858× „
70	1162× „	1291× „	1193× „	1291× „
75	805× „	877× „	796× „	866× „
80	566× „	613× „	548× „	591× „

III. "On Scalar and Clinant Algebraical Coordinate Geometry, introducing a new and more general Theory of Analytical Geometry, including the received as a particular case, and explaining 'imaginary points,' 'intersections,' and 'lines.'" By ALEXANDER J. ELLIS, Esq., B.A., F.C.P.S. Communicated by ARCHIBALD SMITH, Esq. Received February 16, 1860.

(Abstract.)

Scalar Plane Geometry.—With O as a centre describe a circle with a radius equal to the unit of length. Let OA, OB be any two